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Document 20.4
LLNL Occupational Radiation Protection ALARA Program

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20.4

LLNL Occupational Radiation Protection ALARA Program*

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* **Minor revision**

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LLNL Occupational Radiation Protection ALARA Program

1.0 Introduction

As low as reasonably achievable (ALARA) is an approach to radiation protection to manage and control individual and collective whole body dose to employees and visitors to levels as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. ALARA is not a dose limit, but a process for maintaining doses as far as is reasonably achievable below the applicable limits specified in the Department of Energy (DOE) rule on occupational radiation protection (10 CFR 835, Rev. 1, hereafter referred to as the "Rule"). The ALARA philosophy is based on the supposition that penetrating radiation dose increases one's risk of cancer—the smaller the dose, the smaller the risk. Although this premise has not been proven at low doses of radiation (e.g., acute whole-body doses less than 10 rem), the Rule requires formal plans and measures for applying the ALARA process to occupational radiation exposure. A similar process, Environmental ALARA, is applied to potential environmental exposure to members of the public and biota. See Document 31.2, "Radiological Air Quality Compliance", in the *ES&H Manual* for information related to Environmental ALARA.

From a technical and regulatory standpoint, ALARA applies to the Total Effective Dose Equivalent (TEDE) (i.e., the effective dose equivalent (EDE) from external exposure of the whole body plus the committed effective dose equivalent (CEDE) from internally deposited radioisotopes). The TEDE (stochastic) limit of 5 rem/year is based upon establishing a reasonably low occupational latent cancer risk.

Occupational radiation exposure to the extremities, skin, and eyes are considered separately from the whole body, with higher set dose limits . These deterministic (or non-stochastic) dose limits are established to prevent radiation damage to the worker (as opposed to limiting the worker's risk of cancer). Because deterministic exposures have not been shown to contribute to an increased risk of cancer, they are not formally included in the ALARA program. However, from an operational standpoint, it is important to stay well below the dose limits so that operations can proceed without impediment.

This document describes LLNL's formal plans and measures for implementing the ALARA process and applies to all LLNL activities that are subject to the Rule. Effective implementation of this document will ensure compliance with applicable requirements of the Rule. "Dose" and other terms used in this document are defined in Appendix A.

2.0 Formal Plans and Measures

This section provides the administrative and operational guidelines for LLNL's occupational ALARA Program.

2.1 Policy and Management Commitment

Laboratory policy is to conduct radiological operations in a manner that ensures the health and safety of all employees, contractors, and visitors. In achieving this objective, LLNL shall ensure that radiation exposures to its workers and others entering radiologically controlled areas are maintained below regulatory limits, and deliberate efforts are taken to reduce exposures to as low as reasonably achievable.

The Laboratory is committed to implementing a high-quality radiological control program that reflects this policy. The workforce shall comply with this policy when planning or conducting work.

2.2 ALARA Training

ALARA training has been incorporated into General Employee Radiological Training (GERT) and Radiological Worker training. In addition to such general training, mockup training should be considered when preparing for unique tasks during which the dose to workers may be high.

ALARA training for designers and engineers is accomplished via interactions with the Environment, Safety, and Health (ES&H) Team health physicist during the planning and design phases of an operation or facility. Thus, it is imperative that the programs involve the ES&H Team early in the conceptual design process.

2.3 Plans and Procedures

Safety plans are required for radiological operations, as prescribed in Document 20.1, "Occupational Radiation Protection," Document 20.2, "LLNL Radiological Safety Program for Radioactive Materials," and Document 20.3, "LLNL Radiological Safety Program for Radiation-Generating Devices," in the *ES&H Manual*. Information about how to write a safety plan is contained in Document 3.3, "Operational and Facility Safety Plans," in the *ES&H Manual*.

2.4 Design Criteria

During routine operations, the combination of physical design features and administrative controls shall ensure that doses are kept below established limits. Physical design features (e.g., confinement, ventilation, remote handling, and shielding) shall be the primary method of reducing exposures to as low as reasonably achievable. Administrative controls (e.g., plans, procedures, training, and signs) supplement the primary controls. Occasionally, administrative controls are used in place of physical controls if the latter are shown to be impractical. Personal protective equipment (PPE) (e.g., lab coats, gloves, and respirators) provides the third tier of radiological control.

The following objectives shall be adopted during the design of new facilities or modification of existing facilities:

- Optimization methods shall be used in developing and justifying facility design and physical controls. Costs in the range lower than $200–2500 per person-rem reduction in collective dose are generally considered optimized. For example, if adding 6 inches of concrete to the walls of a facility would cost $50,000 and reduce the anticipated collective dose by 10 rem over the life of the facility, the additional cost would not be justified.

  $50,000/10 rem = $5000/rem saved, which exceeds the guideline of $2500/rem saved.

  If the same amount of concrete will save 100 rem, the cost would be justified.

  $50,000/100 rem = $500/rem saved, which is within the guideline range of $200–2500/rem saved.
- Personnel exposure from external sources of radiation shall be limited to 10% of the applicable limit (e.g., a whole-body dose of 0.5 rem/y).

  Note: Although the DOE specifies a design objective of 20% of the applicable limit, LLNL has established this lower criterion as a cost-effective means of accommodating the uncertainties and changing nature of research and development (R&D) operations.
- Under normal conditions, the design objective shall be to avoid releases of radioactive material to the workplace atmosphere and, in any situation, to control the inhalation of such material to levels that are as low as reasonably achievable. Confinement and ventilation shall normally be used.
- Facility design and selection of materials shall include features that facilitate operations, maintenance, decontamination, and decommissioning.
- Structural shielding shall meet the following minimum requirements:
  - All shielding materials shall be of assured quality, uniformity, and permanency.

  - Lead shields shall be protected against mechanical damage and mounted in a manner that prevents cold-flow resulting from the shields' own weight.
  - Joints at the floor and ceiling shall be constructed so that the overall protection of the shield is not impaired.
  - Provision shall be made to ensure that nails, rivets, or screws that penetrate shielding are covered to provide protection equivalent to that of unpenetrated shield. Holes in shields (e.g., for pipes, ducts, conduits, louvers) shall be provided with baffles to ensure that the overall protection afforded by the shielding is not impaired.
  - The lead equivalent of doors and observation windows of exposure rooms, cubicles, and cabinets shall not be less than that required for the shield in which they are located.
  - Clearances around doors (e.g., between the door jam and lintel) shall be shielded to the level required for the door itself.

- A system of fixed, nuclear accident dosimeters shall be installed in facilities where a nuclear accident is possible.

2.5 ALARA Design Review for Facilities and Equipment

The requirement for conducting ES&H evaluations and prestart and readiness reviews is contained in Document 2.2, "Managing ES&H for LLNL Work," in the *ES&H Manual.* The facility manager or Responsible Individual for equipment should ensure that the ES&H Team health physicist participates in reviews relating to the design or modification of radiological facilities and equipment. The health physicist's early and ongoing participation will ensure that radiological considerations are integrated into the design, construction procedures, proposed operating procedures, and plans for decommissioning.

During the design review, the ES&H Team health physicist should

- Review the general configuration of the facility and equipment, considering traffic patterns; location of radiation areas; location and size of changing rooms; adequacy of personnel decontamination facilities; location of fixed survey equipment; and adequacy of space for anticipated operations, maintenance, production, research, and decommissioning.
- Verify that radiological design criteria are consistent with applicable regulations and recognized standards and guides. DOE directives relating to radiological safety design are listed in Section 5.3 of this document.
- Verify that the design of confinement and ventilation systems provides the required level of protection from airborne contamination, giving particular

attention to patterns of air flow and to the locations of air inlets, penetrations, and exhausts.

- Evaluate and confirm the adequacy of specific control devices for reducing occupational doses, including shielding, hoods, glove boxes, containments, interlocks, barricades, shielded cells, decontamination features, and remote-handling devices.
- Verify that the design will be able to maintain personnel entry control for each radiological area, commensurate with existing or potential radiological hazards within the area, by using one or more of the entry control methods listed in the Rule. (The Rule is contained in Document 20.5, "Occupational Radiation Protection: Implementation of 10 CFR 835," in the *ES&H Manual*.)
- Verify that each entrance or access point to High and Very High Radiation Areas will have the entry control features required by the Rule, including provisions for emergency egress.
- Assess the adequacy of planned radiation-monitoring and nuclear criticality safety instrumentation; the appropriateness of the proposed instrumentation for the expected types, levels, and energies of radiation to be encountered; and whether the instrumentation has sufficient redundancy and capability for operation under normal operating conditions and in emergencies.

2.6 ALARA Reviews for Operations

The ES&H Team health physicist shall review each radiological operation requiring an Safety Plan (SP) and document any necessary controls in the SP. The purpose of the review is to identify potential sources of personnel dose and controls necessary to reduce the dose. The review also ensures that appropriate safety controls for normal operations and upset conditions are integrated into radiological operations.

During this review, the ES&H Team health physicist should consider the following:

- Individual and collective dose expected as a result of the operation.
- Potential dose consequence to workers and the public for off-normal operations.
- Whether the projected dose could be reduced or eliminated by using
  - — Less radioactive material.
  - — Shielding, without introducing offsetting problems (e.g., industrial, fire, or criticality hazards).
  - — Tools, such as tongs or holding devices.

- Whether the work area is appropriate for the type of work being conducted (e.g., is a high-hazard job being conducted in a low-hazard area).
- Whether the area is properly posted.
- Whether appropriate monitoring requirements are included in the Health Physics Discipline Action Plan (HP-DAP).

Based on considerations such as these, the health physicist should identify appropriate controls using a graded approach. Typical operational ALARA controls include:

- Using tools, shielding, workplaces, and PPE (including respirators), as appropriate.
- Minimizing time in Radiological Areas.
- Maximizing distance from radioactive sources.
- Monitoring stay-times.
- Effectively using mockup training.
- Requiring a prestart briefing. Prestart briefings should be conducted just before (e.g., within a day of) performing high-consequence or complicated work. They should include a discussion of workplace conditions; the work to be done; the actions to be taken in case of upset conditions; and elements such as the current dose rates, airborne or surface contamination levels, and any stay-time restrictions.

2.7 Dose Investigations

The ES&H Team health physicist shall investigate anomalous dosimeter readings or results that exceed the thresholds identified in Table 1. The results shall be documented, at a minimum, on an Exposure Investigation Request form, and shall be included in the affected individual's personnel dosimetry file. If any of the thresholds in Table 2 is surpassed, the work supervisor shall conduct and document a post-job review. The post-job review shall involve the workers, the ES&H Team, and other individuals that may have impacted or been affected by the situation.

A formal dose investigation shall be conducted for any dose that exceeds the limits specified in 10 CFR 835.202. The investigation report shall be included in the affected individual's personnel dosimetry file.

Table 1. Dosimeter thresholds that trigger an investigation.

Dose[1]	Dosimeter reading (rem)			
	Panasonic 802	Panasonic 810	Panasonic 810/CR-39	Extremity
Deep photon	0.1	0.1	0.3	—
Neutron	0.02	0.03	0.05	—
Deep dose to a DPW or minor worker	0.03	0.03	0.03	—
Shallow	0.1	0.3	0.3	—
Extremity	—	—	—	1

[1] Any positive dose on a dosimeter worn by a visitor is investigated.

Table 2. Thresholds for conducting a post-job review.

1. The actual collective dose exceeds 5 person-rem.
2. The actual dose exceeds the prejob dose estimate by more than 25%.
3. A stop-work order is issued for radiological purposes.
4. Operations result in the issuance of an Occurrence Report.
5. Significant lessons learned are identified.
6. Planned special exposure provisions are used.

2.8 Individual ALARA Goals

The work supervisor, with support from the ES&H Team health physicist, shall identify individuals likely to receive a whole body dose of more than 0.1 rem/y from all operations and establish ALARA goals for these individuals. ALARA goals should:

- Be based on historical radiation doses and projected workload, and may be modified (up or down) during the year to reflect actual conditions.
- Reflect a challenging upper bound of dose that the worker is expected to receive (but is not a dose limit).
- Be approved and issued by management (typically, the facility manager).
- Be tracked to ensure the work supervisor and worker are aware of the accumulated dose. The cause of doses that approach or exceed the ALARA goal should be scrutinized.

On a periodic basis (e.g., every three or four months), the ES&H Team health physicist shall provide supervisors with graphs of individuals' year-to-date dose (see the example in Fig. 1). If a worker is approaching or has exceeded his/her ALARA goal, the supervisor, worker, and health physicist shall evaluate the work to determine if additional dose-saving measures are appropriate. In some cases, exceeding the ALARA goal may simply mean that the individual has had a greater workload than anticipated

at the beginning of the year or has worked with higher dose-rate material. In any case, both the worker and work supervisor should be explicitly aware of the situation.

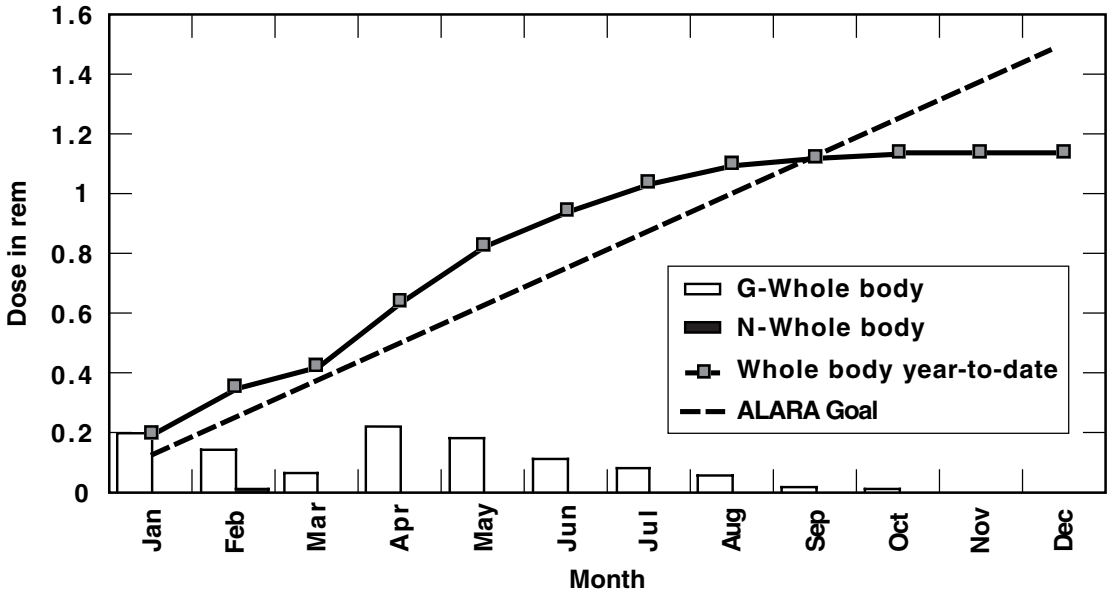

Figure 1. Graph showing an individual's whole-body dose and ALARA goal.

2.9 Formal ALARA Reviews

A formal ALARA review should be conducted based on the criteria in Table 3 and documented using the form in Appendix B. This review does not need to be conducted if the cost, together with the cost of documentation, outweighs the potential value of the benefits. The ALARA review should be conducted in three discrete phases: during the planning phase, while the work is being conducted, and following completion of the work.

Table 3. Conditions requiring a formal ALARA review.

1.	Individual whole body dose from an operation* is expected to exceed 0.1 rem/y.
2.	Collective dose is expected to exceed 1 rem/y.
3.	Predicted concentration of airborne radioactivity is expected to exceed 40 derived air concentration-hours (DAC–h) in a year in areas accessible to individuals.
4.	Work is expected to create High Contamination Areas (i.e., areas with >100 times the values in Appendix D of Document 20.2) outside the immediate work area (i.e., Type I, II, or III workplace).
5.	Entry is required into areas with dose rates exceeding 1 rem/h at 30 cm.

* In this context, an "operation" is an activity that is defined by an authorizing work document.

During the planning phase, the ES&H Team health physicist should:

- Estimate the individual and collective dose.
- Identify tasks that may result in a disproportionate fraction of the dose.
- Identify appropriate ALARA controls and alternatives, and compare the cost of these controls to the cost criteria specified in Section 2.4.

The ALARA controls identified by the ES&H Team health physicist should be incorporated into the operation and the safety plan, as appropriate. The program supervisor and ES&H Team should make periodic inspections during work to ensure that ALARA controls are implemented and are effective.

2.10 Internal Audits

As specified in Document 20.1, LLNL shall conduct internal audits of the radiological protection program to identify its strengths and weaknesses and areas of vulnerability or noncompliance. The audits shall be conducted no less frequently than every 36 months and include examination of the ALARA Program.

2.11 Summary of Program Thresholds

Table 4 summarizes LLNL's ALARA Program thresholds.

2.12 Records

Payroll and program management should review and approve documents and legal records used to demonstrate compliance with the ALARA Program requirements. At a minimum, payroll and program management shall maintain the following records:

- Completed design review package for facilities and equipment.
- Formal ALARA reviews for operations that exceed the thresholds in Table 3.

Records should be detailed enough to support the optimization decisions made for operations that result in an expected annual dose exceeding 1 rem to an individual or an annual collective dose exceeding 5 rem.

Other actions taken to maintain occupational exposures as low as reasonably achievable should also be documented. The level of effort involved in documenting ALARA decisions should be commensurate with the potential dose savings to be realized.

Table 4. Summary of ALARA Program thresholds.

Action	Threshold	Done by
Conduct an operational ALARA review	All radiological operations, as specified in Document 20.2 and Document 20.3	ES&H Team health physicist
Conduct a dosimeter investigation	As specified in Table 1 of this document	ES&H Team health physicist
Establish individual ALARA goals	Individual internal or external doses are expected to exceed 0.1 rem/y (from all operations)	Authorizing organization, with input from ES&H Team health physicist
Conduct a prestart briefing	Complicated or high-consequence work or Individual dose expected to exceed 0.1 rem in a week	Authorizing organization, with input from ES&H Team health physicist
Conduct a post-job review	As specified in Table 2 of this document	Authorizing organization, with input from ES&H Team health physicist
Conduct a formal ALARA review	As specified in Table 3 of this document	ES&H Team health physicist
Conduct a design review as specified in Section 2.5 of this document	Modification of facilities or major equipment	Authorizing organization, with input from ES&H Team health physicist
Maintain detailed records to support optimization decisions made during the design phase	Individual dose is expected to exceed 1 rem/y or The collective dose is expected to exceed 5 rem/y	Authorizing organization

2.13 Consideration of Nonradiological Hazards

Industrial, physical, and chemical hazards that an individual may encounter shall be considered during the planning process. Efforts to maintain radiation doses as low as reasonably achievable should not disproportionately increase the risk of personnel injury from other hazards. The impact of other occupational hazards shall be considered when optimizing worker radiation dose. For example:

- Excessive protective clothing used to control personnel contamination events may lead to heat stress.
- Respirators used to reduce intakes of radionuclides may impair visual acuity and communications capabilities among workers.
- Protective clothing used to protect workers from chemical hazards may slow down work, leading to increased worker dose.

An integrated approach shall be used during the work planning process to ensure that all occupational hazards are appropriately considered and the ALARA process is followed.

3.0 Responsibilities

All workers and organizations shall refer to Document 2.1, "Laboratory and ES&H Policies, General Worker Responsibilities, and Integrated Safety Management" in the *ES&H Manual* for a list of general responsibilities. Specific responsibilities of LLNL organizations and workers who have key safety roles are listed below. These responsibilities are specific to the ALARA Program and are in addition to the responsibilities identified in Document 20.1.

3.1 Authorizing Individuals

Authorizing individuals are responsible for:

- Involving the ES&H Team in the planning phase and design review of facilities, equipment, and operations.
- Maintaining records of formal ALARA reviews, design reviews, and other information to support optimization decisions if individual doses are expected to exceed 1 rem/y or collective doses are expected to exceed 5 rem/y.
- Participating in the ALARA goal process for workers who are likely to receive individual doses exceeding 0.1 rem/year.
- Investigating increasing trends in collective dose and skin and personal clothing contaminations.
- Ensuring that workers are aware of ALARA requirements and the ALARA philosophy.
- Incorporating the ALARA philosophy and ALARA recommendations made by supervisors and the ES&H Team health physicist, as appropriate, in design features and SPs.

3.2 Radiological Workers

Radiological workers are responsible for:

- Informing the work supervisor or the ES&H Team of proposals for reducing exposures.

- Implementing the ALARA requirements specified in plans and procedures.
- Consulting the work supervisor and the ES&H Team prior to beginning work if the whole-body dose could potentially approach or exceed 0.1 rem in a week.

3.3 ES&H Team Health Physicists

ES&H Team health physicists are responsible for:

- Providing technical support and assistance to supervisors, planners, schedulers, principal investigators, and design engineers to reduce occupational doses and the spread of radioactive contamination.
- Providing input for new or modified facilities or equipment during the planning phase to ensure that
  - Design and physical controls are optimized.
  - Internal and external sources of exposure are appropriately controlled (e.g., through use of ventilation systems, filtration, access control systems, and shielding).
  - Materials selected facilitate operations, maintenance, decontamination, and decommissioning.
- Reviewing radiation dosimetry data and conducting investigations if the indicated dose exceeds pre-established criteria. Notifying supervisors and workers of the results of an investigation, as appropriate.
- Providing supervisors with periodic dose reports for individuals with ALARA goals.
- Providing the program or facility with an annual summary of doses received in facilities where the collective dose exceeds 1 rem, including maximum individual and collective doses. Addressing, as appropriate, radiation safety trends, notable problems, and results of air sampling and stack monitoring.

4.0 Work Smart Standards

10 CFR 835, "Occupational Radiation Protection."

5.0 Resources for More Information

5.1 Contacts

The following contacts at LLNL can provide information about LLNL's ALARA Program:

- The program supervisor.
- The authorizing manager.
- ES&H Team health and safety technician.
- ES&H Team health physicist.
- ES&H Team leader.
- Hazards Control Department Radiation Protection Program Subject Matter Expert (RPP-SME).

Hazards Control Department personnel can be reached through the ES&H Contact List.

5.2 Applicable Lessons Learned

The "Radiation Protection" category of the Lessons Learned Program contains information pertinent to ALARA Programs. The Lessons Learned Program is available on the Internet at the following URL address:

http://www-r.llnl.gov/es_and_h/lessons/lessons.shtml

5.3 Other Sources

For additional information about topics discussed in this document, workers should refer to the official version of the following *ES&H Manual* documents available on the Internet:

http://www-r.llnl.gov/es_and_h/esh.html

- Document 3.3, "Operational and Facility Safety Plans."
- Document 20.1, "Occupational Radiation Protection."
- Document 20.5,"Occupational Radiation Protection: Implementation of 10 CFR 835."
- Document 20.2, "LLNL Radiological Safety Program for Radioactive Materials."

- Document 20.3, "LLNL Radiological Safety Program for Radiation-Generating Devices."

The following documents were used to develop this document:

- National Council on Radiological Protection and Measurements (NCRP), Publication 127, "Operational Radiation Safety Program" (1998).
- U.S. Department of Energy, "Occupational ALARA Program," *10 CFR 835 Implementation Guide,* DOE G 441.2–1 (December 1998) (Formerly G–10 CFR 835/B2–Rev 1).

The following DOE directives pertain to radiological safety design and are provided for the convenience of the reader:

- DOE O 420.1A, "Facility Safety," excluding § 4.1.3, ANSI/ANS 8.9, ANSI 8.10 and ANSI/ANS 8.17.
- DOE O 5400.1 Chg.1, "General Environmental Protection."
- DOE O 5400.5 Chg. 2, "Radiation Protection of the Public and the Environment."
- 10 CFR 830, "Nuclear Safety Management."

Appendix A

Terms and Definitions

The terms and definitions provided in this appendix are specific to their use in this document.

As low as reasonably achievable (ALARA)	An approach to radiation protection to manage and control individual and collective dose to the work force and to the general public to as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. ALARA is not a dose limit, but a process whose objective is to maintain doses as far below the applicable limits as is reasonably achievable.
Committed effective dose equivalent (CEDE)	The effective dose equivalent that will be delivered to a person during the 50 years following an intake of radioactive material. The CEDE is measured in units of rem.
Deterministic effects	Effects that increase in severity with increasing dose.
Dose	A general term that refers to the sum of the effective dose equivalent (from external radiation) and the committed effective dose equivalent (CEDE) from internal radiation dose [i.e., the Total Effective Dose Equivalent (TEDE)]. Unless otherwise specified, doses to the extremity and skin are not included in the TEDE. Dose is measured in units of rem.
High contamination area	Any area accessible to individuals where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in Appendix D of Document 20.2.
Planned special exposure	A planned exposure received by a radiological worker only in an exceptional situation (e.g., when alternatives that might prevent a radiological worker from exceeding the routine dose limits are unavailable or impractical). Doses from planned special exposures are accounted for separately from doses received from routine occupational exposure.

Radiological area	Any area within a controlled area defined as a Radiation Area, High Radiation Area, Very High Radiation Area, Contamination Area, High Contamination Area, or Airborne Radioactivity Area.
Stochastic effects	Effects that have an increasing probability of occurring with increasing dose.
Total effective dose equivalent (TEDE)	The sum of the committed effective dose equivalent (CEDE) from internally deposited radionuclides and the effective dose equivalent from external radiation. The TEDE is measured in units of rem.

Appendix B

Formal ALARA Review Form

This form should be used to document formal ALARA reviews, which are typically conducted while the safety plan is being developed. The cost of controls and the cost per person-rem saved should be calculated over the life of the facility or operation and need to be included only if the protective measure will NOT be implemented. This form is available from the ES&H Team.

Operation:_____ Safety Plan No.:_____

Evaluated by:_____ Evaluation date:_____

Estimate of highest individual whole-body dose from this operation:

☐ **>0.1 rem** ☐ **>0.5 rem** ☐ **>1 rem and <5 rem** ☐ **Other:**_____

Estimate of collective whole body dose from this operation:

☐ **>0.5 rem** ☐ **>1 rem** ☐ **>5 rem** ☐ **Other:** _____

Tasks that result in a disproportionate fraction of dose	ALARA controls and alternatives	Cost of controls ($)

☐ **Estimated dose reduction:** _____ **Cost/person-rem saved:**_____

☐ **Controls minimize accident potential but do not directly reduce dose.**

Comments:

Post-job review: ☐ **Not required** ☐ **Required because (see Table 2):** _____

Comments: